ANNUAL REPORT

ONR AASERT GRANT No. N00014-93-1-1134

under

ONR PARENT GRANT No. N00014-89-J-1565

Reporting Period: September 15, 1993 to September 14, 1994

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I. NARRATIVE REPORT

A. Administrative:

As anticipated in the grant proposal, one graduate student (Richard J. Fitzgerald) is now being supported under this AASERT grant, after completion of a 3-year NSF fellowship. The availability of this supplementary funding enabled us to maintain the optimum size (6 graduate students) of the group, rather than cut back to 5 students after the expiration of Fitzgerald's external fellowship support. In addition to funding his salary, the grant is also being used for expenses associated with his research work. To date, the largest expenses have been for time on the SEM used in patterning samples for e-beam lithography, and for liquid helium for cooling samples for electrical measurements.

B. Technical:

The specific project that Fitzgerald is working on is demonstrating the photon-assisted tunneling process across the Coulomb blockade energy gap in mesoscopic tunnel junctions. Photon-assisted tunneling is well established in conventional macroscopic tunnel junctions, and forms the basis of very sensitive millimeter wave detectors for astrophysics applications. In this case, the photons supply the energy needed to tunnel in the presence of the superconducting energy gap, which is a single-particle property. Fitzgerald is trying to see if the same Tien-Gordon formalism that describes this process can also be applied to the case of the Coulomb blockade, where the energy barrier stems from the charging energy of an electron on a mesoscopic metallic island, which is a collective property of the configuration, not of a single electron's energy levels.

In recent work by another student in the group (J. M. Hergenrother), we have shown that, if the island is superconducting, a double-junction transistor configuration similar to that used by Fitzgerald is extremely sensitive to photon-assisted tunneling. Tunneling of a single electron switches the electron number on the island from an even to an odd number, opening up a

conduction channel for about 1 μsec before relaxing. The resulting device has a nominal sensitivity which is much higher than conventional detectors, which are limited to one electron per photon. In these experiments, the photons came from 4K black-body radiation leaking in to the sample through imperfect shielding. Accordingly, the spectrum is broadband, and there are no observable specific sharp features which scale with photon energy as in classic photon-assisted tunneling using monochromatic microwave photons. The immediate object of Fitzgerald's experiment is to demonstrate that such sharp features due to monochromatic microwave photons can be seen in conjunction with the collective Coulomb gap as well as with the single-particle superconducting energy gap.

Problems with fabrication and preservation of samples have delayed the progress of this work to an unexpected degree. For a period of several months, workable samples with the desired parameter values could not be produced. This problem has recently been cured by adding new procedures to more completely drive off moisture adsorbed on the substrate before film deposition is begun. With the new procedures, most of the samples appear "good" when made, but they are very delicate, and often are destroyed by electrical discharges in the process of mounting. Nonetheless, preliminary data have been obtained on one sample, showing the effect of microwave radiation on the I-V characteristic at temperatures down to ~0.3K in the ^{3}He refrigerator. This temperature is not low enough to resolve the expected photon-assisted-tunneling steps with the microwave frequencies which we are able to couple down into the cryostat. The next step is to go to the new dilution refrigerator (bought with supplementary funding from the ONR), so that the temperature can be taken down to ~20mK, where the photon-assisted steps should be resolved if charge noise in the transistor is as low as in our other experiments on good samples.

FORM A2-2

AUGMENTATION AWARDS FOR SCIENCE & ENGINEERING RESEARCH TRAINING (AASERT) REPORTING FORM

The Department of Defense (DOD) requires certain information to evaluate the effectiveness of the AASERT program. By accepting this Grant Modification, which bestows the AASERT funds, the Grantee agrees to provide the information requested below to the Government's technical point of contact by each annual anniversary of the AASERT award date.

1. Grantee identification data: (R & T and Grant numbers found on Page 1 of Grant)

a. Harvard University, President and Fellows of Harvard College
University Name

b. N00014-93-1-1134
Grant Number

c. 4128059---01
R & T Number

d. M. Tinkham
P.I. Name

e. From: 9/15/93 To: 9/14/94
AASERT Reporting Period

NOTE: Grant to which AASERT award is attached is referred to hereafter as "Parent Agreement."

2. Total funding of the Parent Agreement and the number of full-time equivalent graduate students (FTEGS) supported by the Parent Agreement during the 12-month period **prior to** the AASERT award date.

a. Funding: $110,000

b. Number FTEGS: 1

3. Total funding of the Parent Agreement and the number of FTEGS supported by the Parent Agreement during the current 12-month reporting period.

a. Funding: $110,000

b. Number FTEGS: 1

4. Total AASERT funding and the number of FTEGS and undergraduate students (UGS) supported by AASERT funds during the current 12-month reporting period.

a. Funding: $ 46,330

b. Number FTEGS: 1

c. Number UGS: 0

VERIFICATION STATEMENT: I hereby verify that all students supported by the AASERT award are U.S. citizens.

M Tinkham
Principal Investigator

12/28/94
Date